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Monitoring System of 660Wp Solar Panel Connected to the ¾ hp Roasted Coffee Machine

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***Abstract*—The monitoring system in solar power generation is important. It will provide some data for measuring the performances of the overall system. In this paper, a monitoring system of 660Wp solar panels for the roasted coffee machine was introduced. This system uses Arduino Mega as its central processor with some sensors as inputs to measure voltage, current, the temperature of solar modules, and ambient temperature in real-time. These data are stored in a SD card memory for later collections. This monitoring system has been tested under a roasted coffee machine operation for one month. The results found that the data can be acquired based on the setting of every minute. The maximum error of the measurements was less than 1%.**

***Keywords*—Monitoring, solar panel, roasted coffee machine**

I. Introduction

The growth of solar energy around the world is very high [1]. This due to solar energy using photovoltaic (PV) is the main technology for shifting electricity suppliers which cause CO2 side effects [2], [3]. The application of solar panels as a source of electrical energy has been widely applied and studied in various uses such as a source of electricity for street or environmental lighting, traffic lights, water pumps, cooling machines, solar-powered vehicles, for home electricity, business, industry, utilities. It has also been built as a large-scale electricity generator (in MW) connected to the grid network. A lot of research has been and is being made related to solar panels or photovoltaic (PV) as the main part of solar energy. The performance of a solar panel is one of the interesting researches recently [4]. In assessing the performance of a PV, the term performance ratio is used.

PV performance depends on various factors such as solar irradiation, solar radiation, temperature, wind speed, humidity, type of PV technology, dust deposition, and shading [5]. The performance ratio can be determined as the ratio of the PV output compared to the output from the calculation of PV and can be obtained by calculating the irradiation, panel temperature, grid availability, size of the opening area, nominal power output, and temperature correction value [6].

The monitoring system in solar power generation is important. It will provide some data for measuring the performances of the overall system includes an on-grid system [7], [8]. Some monitoring used Phyton [9], internet of thing (IoT) [10], or a low-cost system using Arduino [11]. In this paper, a microprocessor using Arduino Mega 2560-R3 is applied to build a monitoring system for 3 x 220Wp or 660Wp in total solar panel as a low cost monitoring system. An SD card is used to record the data due to this system is implemented in a remote area where the internet signal is poor or sometimes no signal was detected.

II. Proposed Monitoring System

A. Monitoring System

The monitoring system was build using an Arduino Mega2560-R3 as its central processor. This system is used to monitor not only the performances of the PV system but also to monitor all systems of the 660Wp Solar Panel Connected to the ¾ hp Roasted Coffee Machine. This proposed monitoring system is focused on the measurement of current and voltage of the system and the temperature of PV and ambient temperature, that can be seen Figure 1.

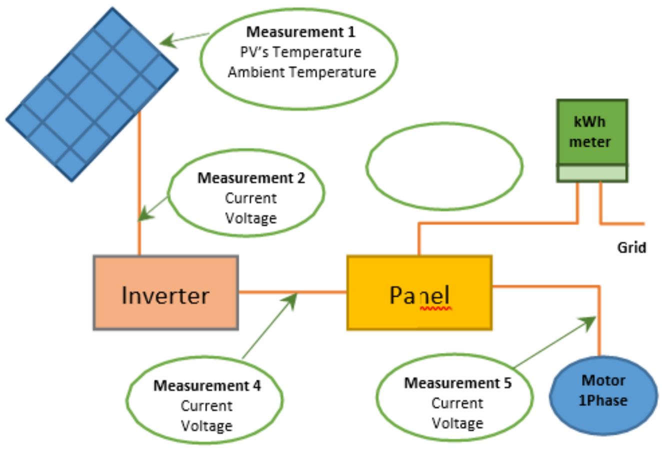

Fig. 1. Some points of measurements in solar power system.

B. PV Performances

There is a general performance measurement indicator for PV systems such as measuring the final yield (YF), reference yield (YR), and performance ratio (PR) [6]. For YF, the energy to load (EPV.AC) in a period time is measured and the rated output power (Po) is already known from the datasheet. This formulation can be denoted as follows:

$$Y_F = E_{PV.AC} / Po \quad (1)$$

YR is in kW and it is the value of the available energy on the field which is calculated in some duration of time. YR is the ratio between total horizontal irradiance on array plane (Ht) with (Wh/m2) and the reference irradiance (G) that is denoted as follows:

$$Y_R = H_t / G \quad (2)$$

After founding the value of YF and YR, then by comparing both values, the ratio of available energy (PR) can be found. It can be formulated in (3). This ratio also represents the performance of the PV system.

$$P_R = Y_F / Y_R \quad (3)$$

Another measurement is an array yield, for the PV to operate in nominal solar generator power (Po) for generating array DC energy EA. The formula can be denoted as follows [6]:

Its units are kW h/d∗kW p.

$$Y_A = E_A/P_O \quad (4)$$

where:

E_A = I_{dc} x V_{dc} x t (kW h)

I_{dc} = DC current (A)

V_{dc} = DC voltage (V)

Po = Nominal Power at STC.

The monitoring system has used some results of measurements that are acquired at the points that are shown in Figure 1. Voltage and current values are used for measuring power using the equation as follows:

$$P = V.I \quad (5)$$

where:

P : power (Watt)
V : voltage (volt)
I : current (ampere)

The result of power calculation then compared to the power of equipment from their technical data, and solar irradiance value to find the Performance ratio (PR) of the solar power system that can be denoted as follows:

$$P_R = \frac{P}{G.A} \quad (6)$$

Where:

P_R = performance ratio
G = solar irradiance (W/m)
A = area of PV installation (m)

C. Proposed Monitoring System

This PV mini-grid monitoring tool was built as a reader or monitors of PV system performances connected to a ¾ hp Roasted Coffee Machine. The panel containing a connected PV panel and consists of 8 sensors, 1 Arduino Mega 2560, an RTC module, an SD card, and other supporting components. The tool will work to monitor 8 aspects of the measurements, which are divided into 2 AC voltage sensors. This sensor uses a voltage transformer as a voltage lowering then connects to a a converter that built using a voltage divider circuit. This converter then convert the voltage value to the data signal that can be connected to Arduino. There are 2 AC current sensors that use of CT sensors with a ratio of 100A: 50mA. Another sensor in this system is a DC voltage sensor using a voltage divider circuit and a DC current sensor using the ACS712 module that has a capacity of 5A. In this tool, there are also 2 temperature sensors using the DHT 11 sensor for detecting the PV panels' temperature and the ambient temperature or temperature of the surround roof where the PLTS panels are placed. All measurement aspects are displayed on the 20x4 type LCD screen and then be recorded as a data logger on the installed SD card. Arduino will acquire the data every 1 minute and then the data is recorded on the SD card. All measurement aspects will be recorded on the SD card with additional time information on it in order to be compared to other data on different time stamped. The accuracy of data recording time is affected by the installation of the DS3231 RTC module, even though the panel is not powered, the time will not change as long as the battery in the RTC module hasenough power.

Fig. 2. Diagram block of monitoring system using Arduino mega.

D. Arduino Mega 2560-R3

The monitoring system for solar power was build using the microprocessor of Arduino Mega 2560-R3 with an SD Card module to record and save the data (Figure 3). The circuit diagram of the power supply can be seen in Figure 4, and three types of sensors were used such as temperature sensor, current sensor, and voltage sensor as shown in Figure 5.

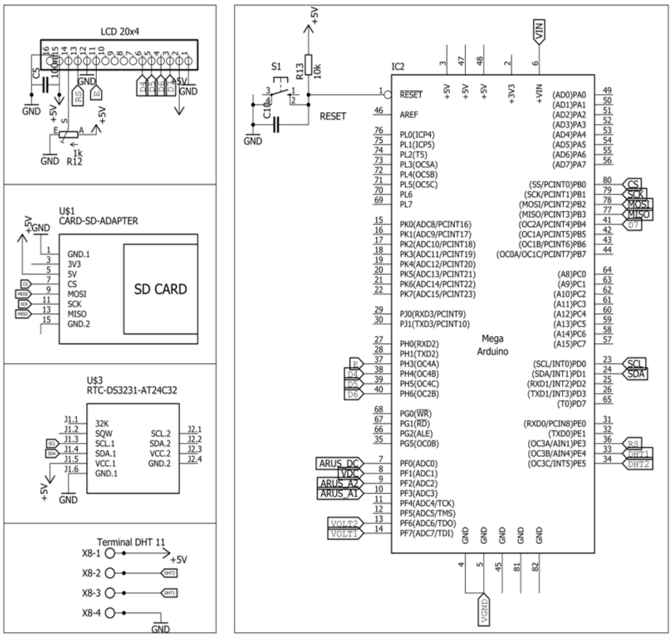

Fig. 3. Circuit diagram of Arduino Mega 2560-R3 and sensors.

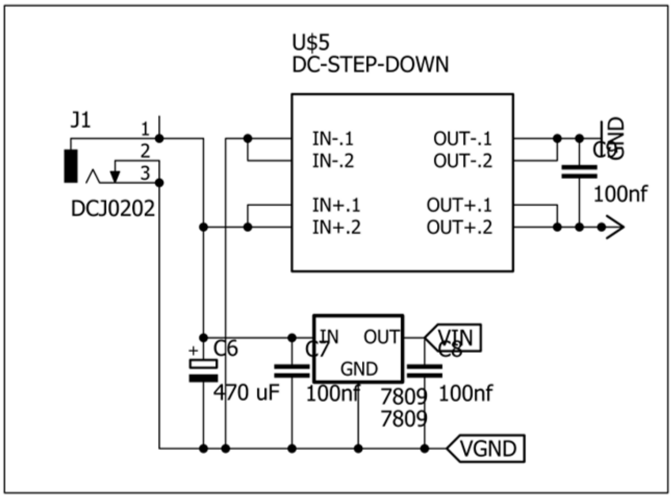

Fig. 4. Circuit diagram of power supply.

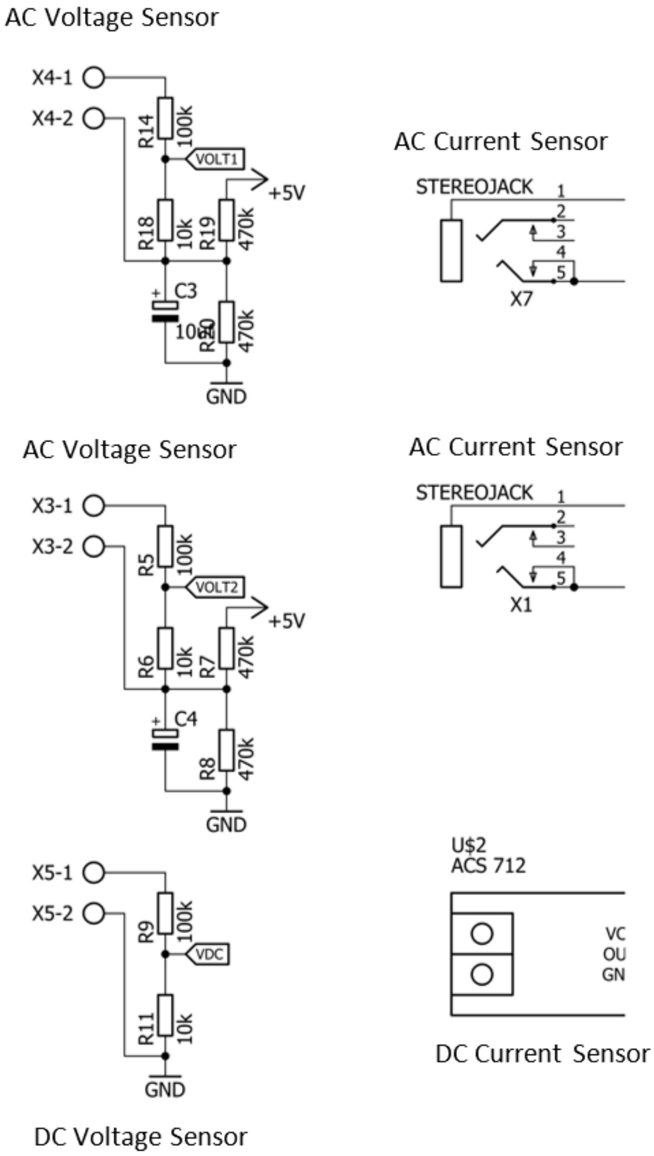

Fig. 5. Circuit diagram of Arduino Mega 2560-R3 and sensor.

III. Results and Discussion

A. The Monitoring Pack

The monitoring system that has been built using Arduino Mega with its layout can be seen in Figure 5 and the complete package that is shown in Figure 6 and 7.

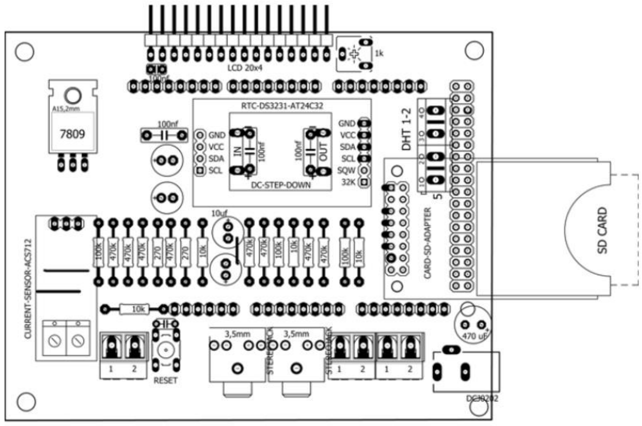

Fig. 6. Layout of monitoring system without sensors.

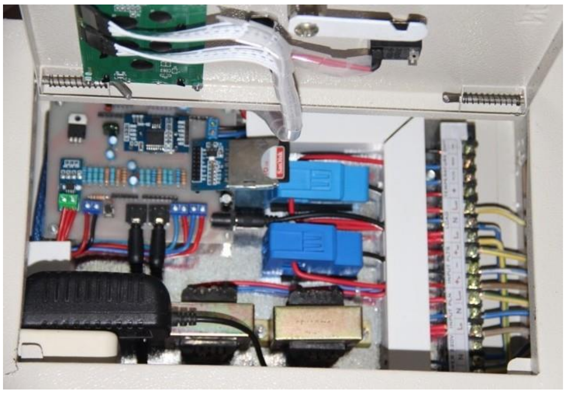

Fig. 7. Inside the box panel of monitoring system.

Fig. 8. Monitoring system panel under the solar power system panel.

B. Test Result

After the monitoring system is built, the test for each partis then conducted. Every sensor is tested for 50 times with random values. These results were compared to the standard tester equipment. The results can be shown in Table 1.

TABLE I. RESULT TEST FOR THE SENSORS

No	Sensor	ΔMax of Measurement
1	Temperature 1	± 0.67%
2	Temperature 2	± 0.33%
3	AC Voltage 1	± 0.05%
4	AC Voltage 2	± 0.09%
5	DC Voltage 3	± 0.83%
6	AC Current 1	± 0.83%
7	AC Current 2	± 0.83%
8	DC Current 3	± 0.50%

From Table 1, the maximum error for the temperature sensor was ±0.67%. This means that the sensors were succeeded in acquiring data of temperature. AC and DC voltage sensors were also operated in good condition with the AC ones had better maximum error compare to DC sensor. On the other hand, DC current sensor had a better result compared to AC currents sensors that have a ± 0.83% of maximum error.

The test was also conducted for storing data in the SD card, and the result found that the system can store the acquired data from all of the sensors. The acquiring time is set to 1:24' (one minute forty-two seconds) and the results is presented in Figure 8.

```
2020/7/19 (SUN) 15:51:12
SHr: 28*C  SHg: 26*C    V1_PLN: 223.0 V  V2_LOAD: 223.0 V  Vdc: 35.9 V    I1_PLN: 3.2 A  I2_LOAD: 3.3 A  Idc: 0.5 A
==========
2020/7/19 (SUN) 15:52:54
SHr: 28*C  SHg: 27*C    V1_PLN: 221.7 V  V2_LOAD: 221.8 V  Vdc: 41.7 V    I1_PLN: 3.3 A  I2_LOAD: 3.3 A  Idc: 0.0 A
==========
2020/7/19 (SUN) 15:54:36
SHr: 28*C  SHg: 27*C    V1_PLN: 217.6 V  V2_LOAD: 216.6 V  Vdc: 41.5 V    I1_PLN: 3.2 A  I2_LOAD: 3.2 A  Idc: 0.2 A
==========
2020/7/19 (SUN) 15:56:18
SHr: 28*C  SHg: 27*C    V1_PLN: 218.9 V  V2_LOAD: 219.1 V  Vdc: 41.6 V    I1_PLN: 3.2 A  I2_LOAD: 3.2 A  Idc: 0.0 A
==========
2020/7/19 (SUN) 15:58:00
SHr: 28*C  SHg: 27*C    V1_PLN: 220.3 V  V2_LOAD: 219.7 V  Vdc: 32.1 V    I1_PLN: 3.1 A  I2_LOAD: 3.2 A  Idc: 0.0 A
==========
2020/7/20 (MON) 07:27:11
SHr: 0*C  SHg: 0*C      V1_PLN: 220.5 V  V2_LOAD: 221.3 V  Vdc: 30.0 V    I1_PLN: 3.1 A  I2_LOAD: 3.3 A  Idc: 5.0 A
==========
2020/7/20 (MON) 07:28:53
SHr: 0*C  SHg: 0*C      V1_PLN: 220.1 V  V2_LOAD: 221.5 V  Vdc: 40.2 V    I1_PLN: 3.1 A  I2_LOAD: 3.2 A  Idc: 4.9 A
==========
2020/7/20 (MON) 07:30:35
SHr: 0*C  SHg: 0*C      V1_PLN: 221.0 V  V2_LOAD: 221.4 V  Vdc: 35.3 V    I1_PLN: 3.2 A  I2_LOAD: 3.3 A  Idc: 7.4 A
==========
2020/7/20 (MON) 07:32:16
SHr: 0*C  SHg: 0*C      V1_PLN: 221.1 V  V2_LOAD: 221.8 V  Vdc: 34.4 V    I1_PLN: 3.2 A  I2_LOAD: 3.2 A  Idc: 7.7 A
==========
2020/7/20 (MON) 07:37:21
SHr: 0*C  SHg: 0*C      V1_PLN: 224.0 V  V2_LOAD: 222.8 V  Vdc: 39.4 V    I1_PLN: 3.2 A  I2_LOAD: 3.2 A  Idc: 6.5 A
==========
2020/7/20 (MON) 07:40:44
SHr: 0*C  SHg: 0*C      V1_PLN: 219.1 V  V2_LOAD: 219.6 V  Vdc: 37.9 V    I1_PLN: 3.1 A  I2_LOAD: 3.2 A  Idc: 7.7 A
==========
2020/7/20 (MON) 07:42:26
SHr: 0*C  SHg: 0*C      V1_PLN: 218.4 V  V2_LOAD: 220.1 V  Vdc: 39.8 V    I1_PLN: 3.1 A  I2_LOAD: 3.2 A  Idc: 5.6 A
==========
2020/7/20 (MON) 07:44:07SHr: 32*C  V1_PLN: 217.7 V  V2_LOAD: 219.2 V  Vdc: 37.3 V    I1_PLN: 3.0 A  I2_LOAD: 3.1 A  Idc: 3.4 A
==========
2020/7/20 (MON) 07:45:49
SHr: 0*C  SHg: 0*C      V1_PLN: 218.3 V  V2_LOAD: 218.7 V  Vdc: 35.7 V    I1_PLN: 3.1 A  I2_LOAD: 3.2 A  Idc: 4.0 A
==========
```

Fig. 9. Acquired data that is stored in SD Card.

For the display of this monitoring system, a 20x4 LCD is used. This LCD is enough to display the acquired data of 3 currents and 3 voltages both in AC and DC, and also the temperature of the PV panel and ambient temperature in real-time. It can be seen in Figure 9.

Fig. 10. LCD for displaying the acquired data in real time.

IV. Conclusion

This monitoring system is built using an Arduino 2560-R3 as a microprocessor with 6 sensors of voltages, currents, and temperatures. For displaying the acquired data in real-time, a 20x4 LCD is used. Data from the acquiring process is stored in an SD Card for later processes. This monitoring system has been tested under a roasted coffee machine operation load for one month. The results found that the data can be acquired based on the setting of every 1 minute and 42 seconds. The maximum error of the measurements for both current and voltage was less than 1%.

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